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SIMULATION OF THE PRECIPITATION SCENARIOS ON THE RIVER CATCHMENT WITH CONSIDERATION OF THE CLIMATIC CHANGES

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Abstract

Usually parameters of water reservoirs are determined on the base of water balance equation with discreteness 10 days (decade). The values of such equation are calculated on the data base for the long time series. Last half of century is observed a change of different climatic characteristics, in particularity precipitations, which are an element of water balance and has very significant influence on runoff to water reservoir. Consequently there is need to simulate precipitation according to last time of series which has more short duration but more reality. However we must take to consideration a big amount of different scenarios of precipitation both for annual values and for the internal year intervals.

Accordingly main purpose of the scientific work is the checking of the method for simulation artificial rows of precipitation according to climatic changes. The next problems were decided: determination of statistical parameters and trends according to data observation for the precipitation; assessment of stationary of the time series of observations; simulation of artificial rows of precipitation according to climatic changes; check of the method for simulation artificial rows of precipitation.

Object of research was chosen a catchment of water reservoir of Moscow region.

The method Monte Carlo (variant of fragments) was used for simulation of precipitation on territory of the river catchment. The results have showed that the used method can be applied for simulation of precipitation for the studied object. It is obviously that the method must be verified for each object, and if it is necessary-the method may be changed.

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1. Introduction

The precipitations on the catchment participates in forming of runoff and they are element of water balance of water reservoir. Last time we can notice, that amount of precipitation is changed according to climatic changes on some territories. The object of research in the scientific work was change of data observation for precipitation on meteorological station of Mozhaysk city which define runoff value to the Mozhaysk water reservoir. There is necessary to considerate different scenarios of precipitation distribution relative time for successful flow regulation by water reservoir with assessment of climatic change.

2. Materials and methods

The statistical rank of the precipitation on the Mozhaysk meteorological station has long time observations 78 years (1936-2013). The graph of the annual precipitation values is represented on fig.1.

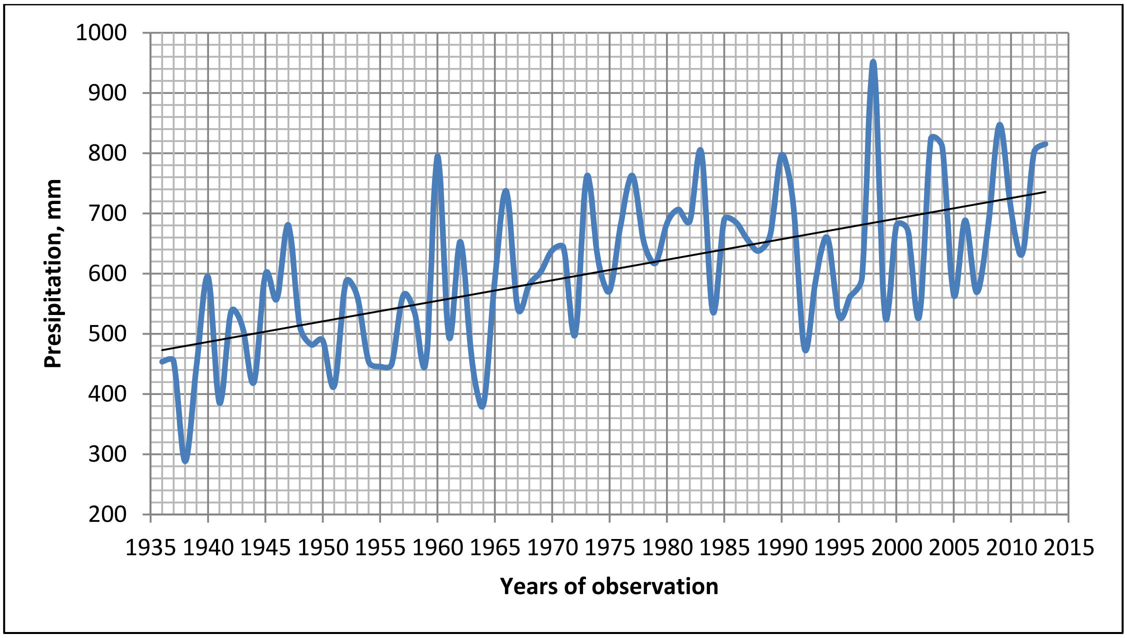

Fig. 1. Changes of the annual precipitation.

We can see on fig.1 that there is clean trend of increasing of annual precipitation during time.

Statistical homogeneity of values was checked with help of known criterions of Fisher and Student's t-test on the base of two statistical ranks: 1936-1974 and 1975- 2013. In result a hypothesis of homogeneity has not been confirmed since Student's t-test (t=5,78) exceeded acceptable limits of homogeneity significantly. Accordingly we can say that the second half of observed data is more real for successful flow regulation by water reservoir. However, we must have a significant amount of scenarios of precipitation relative to annual values and within annual values. But the short statistical rank (1975- 2013) does not contain various combinations of periods of small or large precipitation in the annual and the internal value of the year. It is Therefore it is necessary artificial simulation of long time series (about 300 years) to obtain them. So, next problem of the study – the checking of method for simulation artificial time series of precipitation on the base of comparison the statistical parameters of observed and simulated time series. The main statistic characteristics of the artificial long-time series should not differ substantially from similar characteristics of time series data for the last 39 years.

Simulation of the artificial time series was done with help of the Fragment way of Monte-Carlo method [1]. The method uses twice modelling. At first, the ranks of annual precipitation were modelled by method Monte Carlo. Then within each year – the decade (ten days) values of precipitation were modelled with help fragments, which were selected randomly (Monte Carlo method was used again) on the base of distribution of precipitation within observed annual values.

Probabilities of annual values for artificial long time series were modelled within interval [0 – 1] according to formula:

$$P_{i+1} = 0{,}5 + R_p \times (\xi_i - 0{,}5) \tag{1}$$

Here:
i – number of year for artificial long time series [i =1- Iend];
Iend - total amount years of artificial long time series;
P – probability within interval [0 – 1];
R_p - correlation coefficient between probabilities of values of adjacent years;
ξ_i – the independent casual values which are modelled according to equal-distributed low within interval [0 – 1].

Then, on the model of probability values - annual values of precipitation were modelled using probability distribution law, which has been selected on the basis of statistical indicators of observational data in a short rank (39 years) [2,3].

The artificial statistical rank of annual rainfall is adequate with respect to the observation data time series (Average of the original rank was 670 mm and variation coefficient - Cv was 0,18, accordingly average of the simulated rank is equal 675 mm and Cv = 0,16).

Differences of statistical characteristics (average and *Cv*) not must exceed errors which is calculated on the basis of time series data according to formulas:

$$Ex_v = \frac{C_v}{\sqrt{n}} \times 100\% \tag{2}$$

$$E_{C_v} = \frac{1}{n+4C_v^2} \times \sqrt{\frac{n(1+C_v^2)}{2}} \times 100\% \tag{3}$$

Here:
n – amount of members in statistical rank (*n*=39).
Each fragment is represented by a set of 36 coefficients (36 for decades - ten days) in a year.
Accordingly coefficients for precipitation were calculated:

$$Kx_{j,i} = \frac{X_{j,i}}{X_{\ i}} \tag{4}$$

Here:
X(i) – precipitation [mm] for every year (i, i=1-39);
X(j,i) - precipitation [mm] for every decade (j, j=1-36) during year (i).
So, Kx (j,i) – share of precipitation for decade (j) relative to annual precipitation during year (i).

During of modelling process - number “m” of fragment is chosen with help casual value, which is modelled according to special program. Accordingly number “m” is equal-probable value among all numbers of fragments. So, artificial long time series (300 years) relative to precipitation were simulated with discreetness decade (10 days). The checking of the obtained artificial long time series was done by comparison of the statistical decade characteristics (averages, *Cv*) of observed values (for the 39 years) and simulated values (300 years). Their differences (Delta) were evaluated with respect to the errors that have been calculated by the formulas (2) and (3). Results are represented in table 1.

Analysis of table 1 has showed that the simulated artificial long time rank almost has not significant differences in respect to average values and Cv. A comparison of statistical characteristics of precipitation in annual and decadal intervals allows us to conclude that the simulated series is virtually adequate relative to observed data and it can be used to evaluate the probability of occurrence of the storm situations and of dry periods during several decades (ten days).

Table 1. Comparison of statistical characteristics of observed and simulated ranks.

Month, decade.		Average		Cv	
		E, %	Delta, %	E_{Cv}, %	Delta, %
January	1	9,427678	-10,2648	12,68837	16,51909
	2	10,35148	-11,7993	12,92851	12,83718
	3	9,931213	-9,8033	12,81796	13,70391
Febrary	1	10,39075	-2,3512	12,93894	11,20014
	2	11,62371	-11,0021	13,27406	13,39019
	3	15,92137	-15,0254	14,4972	7,860118
March	1	19,05549	-18,7457	15,36792	-1,82978
	2	14,29405	-16,8531	14,03105	4,522631
	3	9,947274	0, 94464	12,82215	12,85619
April	1	15,11676	2,118373	14,26712	-3,32229
	2	16,6743	-9,15493	14,71087	3,148834
	3	14,84841	2,719665	14,19016	2,038978
May	1	12,91396	-0,16783	13,63648	6,690586
	2	15,8342	-6,59505	14,47235	-10,5632
	3	13,84826	-6,67647	13,9032	-0,21911
June	1	13,69057	-11,2099	13,85804	2,133268
	2	10,04757	-12,3608	12,84836	9,042141
	3	11,49098	-11,2148	13,23736	13,55635
July	1	15,49897	-13,7191	14,37658	-1,10555
	2	12,16039	6,426332	13,42368	1,579009
	3	12,58172	-2,11974	13,54233	-3,4873
August	1	12,60034	2,134182	13,54759	1,930213
	2	15,10806	-3,24253	14,26463	-3,68514
	3	13,62983	-9,91725	13,84065	3,552947
September	1	11,29284	-6,38321	13,18282	10,60043
	2	13,71629	-16,2831	13,8654	2,495853

	3	13,55959	2,033717	13,82056	1,416522
October	1	14,21332	-8,68768	14,00789	-3,71235
	2	12,91409	-4,03281	13,63652	5,323184
	3	12,5517	-11,4107	13,53384	11,50823
November November	1	10,26903	-13,7863	12,90666	14,42784
	2	12,16527	-12,0364	13,42505	0,858196
	3	10,91365	-12,9546	13,07938	5,381054
December	1	10,39893	-9,75938	12,94112	6,89567
	2	12,58469	-14,2967	13,54317	11,4316
	3	10,3125	-12,54	12,91817	18,35917

3. Conclusions

Basic statistical characteristics of precipitation of the Moscow region for the last 39 years differ from those same characteristics in the last 79 years.

The Monte Carlo on the way "fragment" for simulation of precipitation gave satisfactory results and the possibility to take to consideration of different scenarios with respect to the combination of dry and wet periods.

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